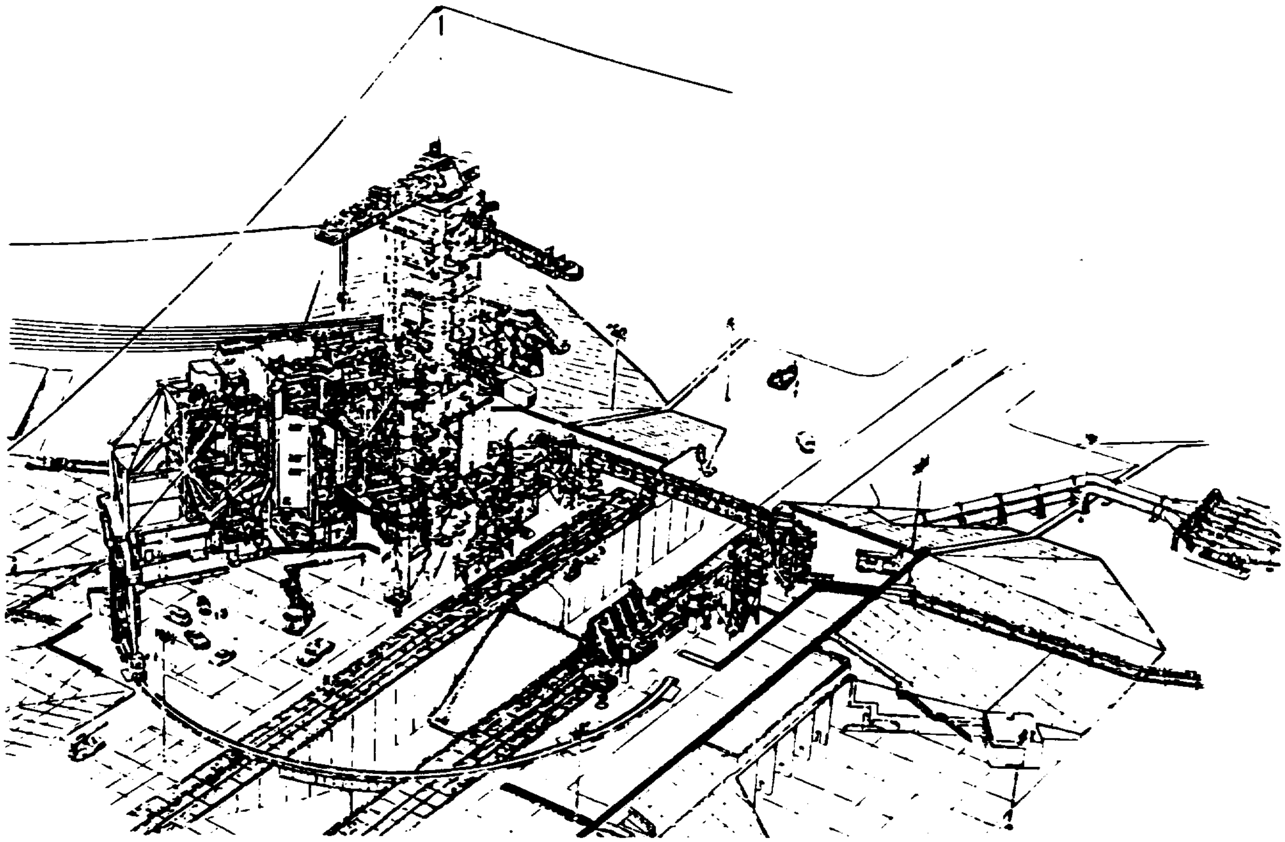
LSO-000-286-1410

KSC ADVANCED PROJECTS & TECHNOLOGY OFFICE

LIQUID ROCKET BOOSTER INTEGRATION STUDY



EXECUTIVE SUMMARY
VOLUME I OF V

FINAL REPORT
PHASE I

NAS10-11475

NOVEMBER 1988

Lockheed
Space Operations Company

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VOLUME I

EXECUTIVE SUMMARY

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VOLUME I OF V
EXECUTIVE SUMMARY

KENNEDY SPACE CENTER
NAS10-11475

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LRBI FINAL REPORT
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VOLUME II - STUDY SUMMARY

SECTION 1: LRBI Study Synopsis - An assessment of the study objectives, approach, analysis, and rationale. The study findings and major conclusions are presented.

SECTION 2: Launch Site Plan - An implementation plan for the KSC launch site integration of LRB ground processing. The plan includes details in the areas of facility activations, operational schedules, costs, manpower, safety and environmental aspects.

SECTION 3: Ground Operations Cost Model (GOCM) - The updating and enhancement of this NASA provided computer-based costing model are described. Its application to LRB integration and instructions for modification and expanded use are presented.

SECTION 4: Cost - Summary and Analysis of KSC Costs.

VOLUME III - STUDY PRODUCTS

The study output has been developed in the form of nineteen derived study products. These are presented and described in the subsections of this volume.

VOLUME IV - REVIEWS AND PRESENTATIONS

The progress reviews and oral presentations prepared during the course of the study are presented here along with facing page text where available.

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VOLUME I

EXECUTIVE SUMMARY

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VOLUME I

EXECUTIVE SUMMARY

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SECTION 1
STUDY BACKGROUND AND FINDINGS

As a part of the overall recent STS program assessment, Liquid Rocket Boosters (LRB) are being evaluated. The LRB could improve STS payload capability/flexibility of operations. NASA-MSFC initiated LRB design studies with General Dynamics and Martin Marrietta. NASA-KSC conducted a study with Lockheed Space Operations Company (LSOC) to assess launch site integration of the LRB, the impact on facilities and operations, costs, and to provide launch site feedback to the design studies.

The LSOC study activity was performed by a study team located in Titusville, Florida. The study team included Pan Am World Services in the assessment of operational efficiencies of LRB launch site processing, and Rocketdyne for the evaluation of LRB engine processing approaches. In addition, NASA/JSC and their contractor, Lockheed Engineering and Sciences Company (LESC), evaluated the LRB/STS Level II integration issues.

The three NASA center/contractor working groups have established a network of direct communications (Figure 1.0) which was used to exchange LRB requirements and impacts.

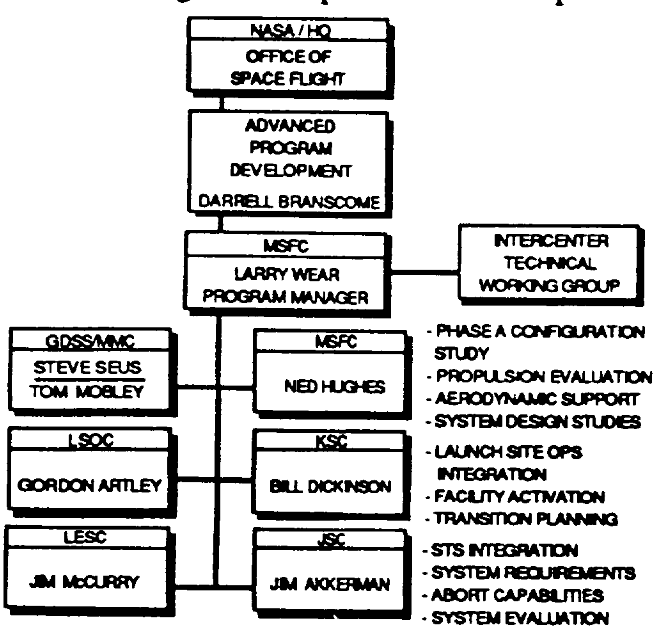


Figure 1.0. NASA/Contractor LRB Working Group.

The KSC Liquid Rocket Booster Integration (LRBI) Study Team utilized this communication network to the fullest extent possible in the conduct of its study tasks.

1.1 PROGRAM OBJECTIVES

The purpose of the LRB study (Figure 1.1-1) was to assess the feasibility of replacing the STS Solid Rocket Boosters with Liquid Rocket Boosters.

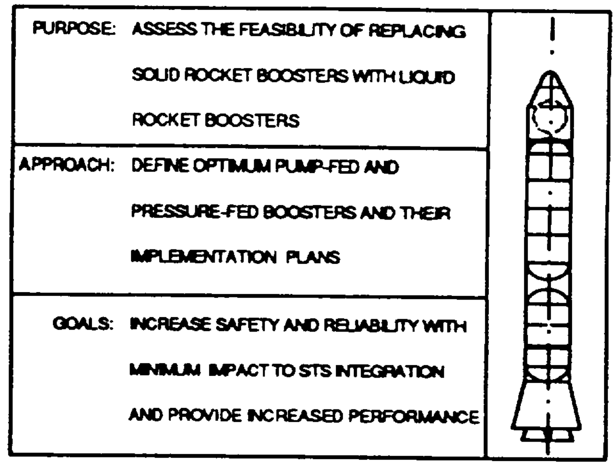


Figure 1.1-1. LRB Program Objectives.

The KSC LRBI Study Objectives are shown in Figure 1.1-2.

- DEFINE FACILITY IMPACTS
- DEVELOP OPERATIONAL SCENARIOS
- PROVIDE BOOSTER DESIGN RECOMMENDATIONS
- PROMOTE OPERATIONAL EFFICIENT LRB SYSTEMS
- PERFORM COST ASSESSMENT UTILIZING GOCM
- GENERATE PRELIMINARY PROCESSING LSE-GSE REQUIREMENTS
- CREATE LAUNCH SITE SUPPORT PLAN

Figure 1.1-2. KSC LRBI Study Objectives.

The first phase of the study was conducted from January through November 1988 with the final report delivered in December, 1988. The study was composed of nine integrated tasks. They were structured to achieve maximum interface with the LRB design team, and to provide them full visibility to the KSC launch site requirements. The LRBI study generated KSC operation scenarios, impacts, cost estimates, and preliminary plans.

The LRBI goal was to accommodate the Shuttle/LRB system with minimum impact to the STS KSC ground processing operations.

At the top level, one overall program finding is noted.

Program Finding: The Shuttle using liquid fueled boosters can, with proper planning and expert program execution, accomplish 122 launches from 1996 to 2006 at KSC.

It is the conclusion of this study that the sustained operation of the STS/LRB can potentially achieve 14 launches per year starting in 1996. There are some major risks and program challenges during the earlier start-up years which could delay achieving the launch rate, or worse, degrade the sustained operations launch rate. Realization of the LRB processing potential at KSC is a major challenge to be shared between the booster designers and the KSC ground processing design and planning community. Continued integration, study and planning is required.

1.2 SIGNIFICANT STUDY FINDINGS

The significant study findings are shown in Figure 1.2-1.

Finding 1: The transition from STS/SRB operations to STS/LRB operations in a non-disruptive manner to the ongoing (phase down) STS/SRB operations presents an unprecedented NASA/KSC challenge. Transition has significant schedule and cost risk. KSC needs a dedicated activation team for activation and transition planning. This team should follow through to implement the new booster operations.

Finding 2: New LRB facilities plus some modifications to existing facilities are required. These include 2 new Mobile Launcher Platforms (MLP), a new Horizontal Processing Facility (HPF) and modifications to the Launch Pads A and B.

Finding 3: Seventy percent of the LRB preliminary design requirements have significant ground systems implications and most design features drive ground systems design (KSC non-recurring cost). Schedule risk and recurring costs are relatively insensitive to LRB design options, but LOX/LH2 is the KSC preferred propellant choice for LRB.

Finding 4: The LRB has a potentially significant and shorter integration timeline on the MLP in the VAB, compared to SRB. This potential reduces launch rate risk (providing the ability to increase launch rate) and launch schedule risk.

Finding 5: Preliminary analysis has identified LRB launch pad clearance problems (metal to metal contact) during ascent. The extent of engineering required to achieve a solution and the magnitude of the solution is unknown.

Finding 6: Cost and launch schedules are sensitive to program planning factors and the degree of achieved booster processing friendliness. Reductions in cost estimates and schedule risks may be realized through the implementation of sweeping innovation (other than currently planned processing enhancements i.e., electronic scheduling - LPS II).

Finding 7: The KSC LRB program costs are approximately $1 billion dollars non-recurring and $1 billion dollars recurring, for a total of $2 billion dollars over a ten-year life cycle (122 missions).

Figure 1.2-1. Study Findings.

Finding 1: The Transition from STS/SRB operations to STS/LRB operations in a non-disruptive manner to the ongoing (phase down) STS/SRB operations presents an unprecedented NASA/KSC challenge. Transition has significant schedule and cost risk. KSC needs a dedicated activation team for activation and transition planning. This team should follow through to implement the new booster operations.

The overall STS/LRB launch life cycle spans a 15 plus year period, and consists of three major activities: Activation, Transition and Operations. The activation occurs during the first ten years of the life cycle. Activation establishes the capability to process and launch the STS/LRB at KSC. It includes the modification and construction of facilities, LSE, GSE, certification, testing, and other activities.

The launch site plan has developed a two phased activation process (Figure 1.2-2) which incrementally provides (in two steps) the capability to launch 14 STS/LRBs per year. STS/LRB launches commence at the completion of the first activation increment. The period of time between preparations to process the first (pathfinder) STS/LRB and completion of the SRB phaseout is called the transition period.

During transition, the Shuttle program resources at KSC are shared between two functioning Shuttle booster configurations. These resources themselves are undergoing a change in configuration in order to accommodate the STS/LRB while continuing to provide support to the ongoing STS/SRB operation. The change to resource configuration at KSC is accomplished by the activation process. The occurrence of the activation process concurrent with the operation of two management and coordination challenge.

It is estimated the KSC non-recurring cost for activation and transition is in excess of one

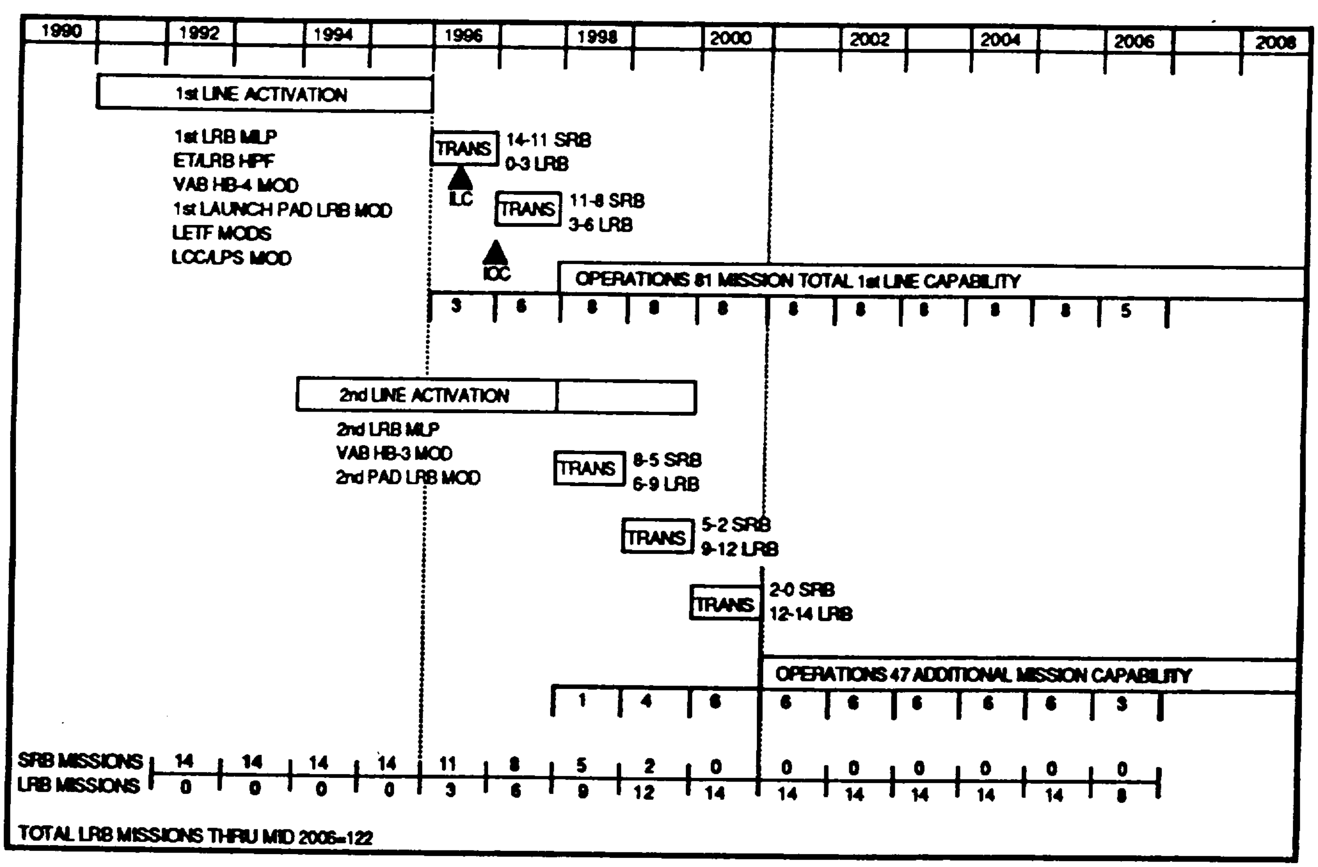


Figure 1.2-2. KSC SRB To LRB Transition Plan.

billion dollars (FY 87 dollars). It is also estimated that a one year slip in transition could cost the STS/Shuttle program $5 billion dollars to recover the lost launches in the future (one additional life cycle year x $5B dollars).

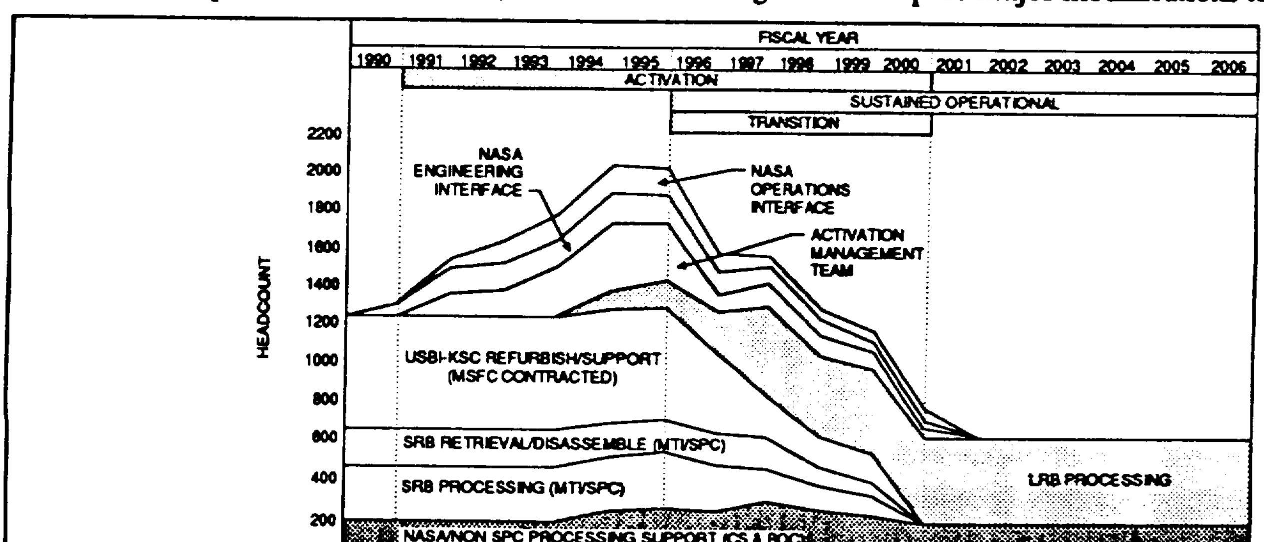
There are three aspects to transition schedule risk. The first is the interference with ongoing STS/SRB operations, the second is the late realization of STS/LRB operations and the third is the concurrent degradation of both STS/LRB and STS/SRB operations. A degradation of launch rate and launch schedule may have non-monitary DOD impacts besides an impact to life cycle cost.

A feeling for the magnitude of the transition process can be obtained from an examination of the additional manpower required to support it (Figure 1.2-3). The transition manpower peaks in FY94-FY95 to 800 additional support operations personnel and an additional 1500 construction, and installation personnel (A&E personnel are included).

Shuttle operations are very sensitive to activation and transition. Continued in-depth analysis is necessary to plan a minimum cost and schedule risk activation and transition. It is advised the planning team become the core of the implementation team, thereby transferring the expertise and smoothing the "change over" to implementation. This would reduce implementation start-up and learning delays. It would also provide the needed expertise to effect change (recovery) efficiently when needed to accommodate program problems.

Finding 2: New LRB facilities plus some modifications to existing facilities are required. These include 2 new Mobile Launcher Platforms (MLP), a new Horizontal Processing Facility (HPF) and modifications to the Launch Pads A and B.

The launch rate of 14 per year and the transition from STS/SRB to STS/LRB requires two new MLP's (Figure 1.2-4). The LRB configurations require major modifications to



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
TOTAL	1342	1597	1704	1789	2050	2024	1603	1546	1295	1145	719	608	608	608	608	608	608
NASA OPERATIONS INTERFACE		36	123	145	145	145	116	58	44	44	15						
NASA ENGINEERING INTERFACE	79	157	142	136	127	127	102	64	57	51	44						
ACTIVATION MGMT. TEAM		141	176	246	363	286	83	96	139	69	92						
LRB PROCESSING					110	147	221	441	441	441	441	441	441	441	441	441	441
USBI REFURB/SUPPORT	600	600	600	600	600	600	474	342	216	200							
SRB RETRIEVAL/DISASSEM.	160	160	160	160	160	160	128	91	57	50							
SRB PROCESSING	336	336	336	336	336	336	264	192	129	100							
NASA/NON-SPC PROC. SUPP.	167	167	167	167	209	223	217	262	227	190	167	167	167	167	167	167	167

Figure 1.2-3. Time Phased LRB Integration Headcount.

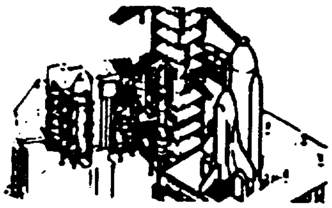
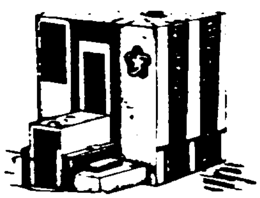
CRITICAL ACTIVITIES	CONCERNS
 MODIFY TWO PADS	PAD MODIFICATIONS TIMELINE DO NOT FIT THE AVAILABLE OPEN WINDOWS AT 14 LAUNCHES PER YEAR. DURING LRB PAD MODIFICATION, 8 MONTHS OF EXCLUSIVE ACCESS MAY BE REQUIRED.
 CONSTRUCT TWO NEW MLP'S	NEW MLP DESIGN AND CONSTRUCTION IS THE CRITICAL PATH ACTIVITY TO MEET THE FIRST LRB LAUNCH IN FY96.
 MODIFY VAB HIGH BAY 4 AND HIGH BAY 3	PRESENTS A COORDINATION PROBLEM WITH ONGOING SRB/ET ACTIVITIES, I.E. CLEARING ZONES DURING SRB STACKING.

Figure 1.2-4. Critical Activation Activities.

the existing SRB/MLP. The flame hole enlargements required for LRB impacts the primary structural girders. MLP commitments for SRB launch rates do not allow modification windows without impacting launch schedules.

Relocation of the ET processing activity to a remote site (Horizontal Processing Facility-HPF) facilitates the conversion of VAB HB-4 to a full integration cell for LRB. This is required to avoid launch schedule interruption to the on-going STS operations. At a rate of 14 launches per year HB-1 and HB-3 are fully utilized (no modification windows). Placing LRB processing in a remote location from the VAB reduces required lifts and facilitates standalone operations without VAB "hazardous clears". These two major issues justify the planning for the new LRB/ET Horizontal Processing Facility (HPF).

The launch pad will require modifications. The flame trench is a concrete and steel channel that contains the launch exhaust and protects the pad structure from blast and exhaust flames. There are three flame deflectors (two side and one main).

The two exhaust holes on the existing MLPs are not sized properly for the LRB. The new MLP exhaust holes subjects the Pad to exhaust impingement and results in back pressure which may impact the Orbiter. The new MLP will utilize the flame deflectors which were originally intended to channel the exhaust flame, as a flame trench extension. This new role requires the flame deflectors to have greater strength and flame corrosion resistant integrity. This will substantially increase the weight of the deflectors.

The location of the new flame deflectors will interfere with the MLP crawler. The LRB flame deflectors must be removed from the launch position each time the crawler moves the MLP to and from the launch pad. The LRB portable flame deflector moving operations presents a design and operations challenge which could introduce delays to both the transition/activation and operations launch phases.

Finding 3: Seventy percent of the LRB preliminary design requirements have signif-

icant ground systems implications and most design features drive ground systems design (non-recurring cost). Schedule risk and recurring costs are relatively insensitive to LRB design options, but LOX/LH2 is the KSC preferred propellant choice for LRB.

The KSC LRB Study Team performed an assessment of the documented LRB Design Requirements found in the General Dynamics final report. These requirements were developed from study goals and assumptions and applicable program level requirements. Almost 70% of these preliminary booster design requirements have ground system implications. It is certain from this assessment that booster design and ground system design/redesign will be a significant integration challenge during subsequent study.

The study has found booster option processing requirements to be insensitive to booster option. Timeline variations are small, spare and consumable requirements differ slightly, and processing costs are similar.

There are a number of reasons LOX/LH2 is preferred. They are: (1) LOX/LH2 is environmentally the least harmful propellant; (2) Oxygen and Hydrogen are readily and easily acquired;. (3) It is a familiar propellant to KSC; and (4) LOX/LH2 reduces MLP and flame deflector design (technical) risk as the least abrasive and coolest burning fuel; (5) LOX/LH2 engines provide the smallest impingement diameter, thereby minimizing MLP hole and side deflector impingements. This reduces the MLP and side deflector technical, and schedule risks.

LOX and LH2 does have the highest non-recurring cost, a $125 million dollar increase over LOX/RP-1. Recurring costs are virtually insensitive to propellant.

Finding 4: The LRB has a potentially significant and shorter integration timeline on the MLP in the VAB, compared to SRB. This potential reduces launch rate risk (providing the ability to increase launch rate) and launch schedule risk.

The LRB provides a potential 20 day decrease in the overall Shuttle flow. This besides reducing launch rate and launch schedule risk, can also provide a significant opportunity to increase launch rate (see Figure1.2-5). This streamlined flow potential

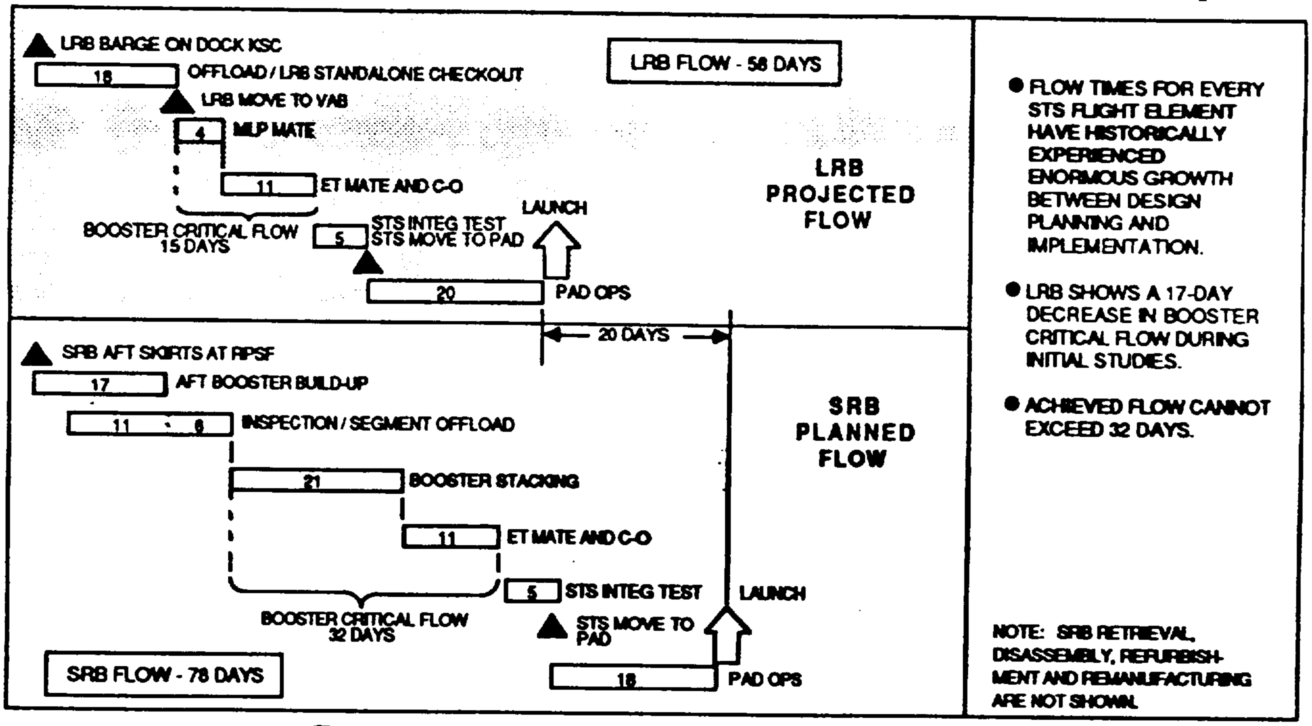


Figure 1.2-5. Generic LRB/SRB Process Flow Comparison.

may also apply to Shuttle manned and unmanned derivatives which employ Liquid Rocket Boosters. Therefore, the realization of the LRB shorter flow potential is important.

SRB planning to achieve 14 launches per year provides 32 days for the booster critical flow. Current LRB projections are 15 days for booster critical flow. The current SRB planning provides an upper bound for the LRB. Exceeding the upper bound prohibits the achievement of the 14 launches per year under current planning. Therefore, in order to assure launch rate and launch schedule compliance, turnaround performance should become a quantitative contractual requirement for the booster development contractor.

Achieving launch rate and launch schedule is important for two reasons. First, life cycle cost is sensitive to launch rate, and second, National security (DOD) payloads and scientific payloads are often sensitive to launch windows (which requires launch schedule compliance).

Finding 5: Preliminary analysis has identified LRB launch pad clearance problems (metal-to-metal contact) during ascent. The extent of engineering required to achieve a solution and the magnitude of the solution is unknown.

A preliminary LRB ascent analysis was conducted using LRB dimensions and geometry and the SRB ascent profile. This analysis indicates that, based on the SRB thrust to weight ratio, there would be metal-to-metal contact during launch. Since the LRBs have a lower thrust to weight ratio at liftoff (in comparison to the SRB) the problem is expected to be more severe.

A more complete analysis is required which includes the LRB ascent profiles and considers worse case scenarios. The nature and magnitude of the engineering solution is unknown. Therefore, the impact to schedule and cost have not been assessed. Further study by the NASA/contractor working group is required.

Finding 6: Cost and launch schedules are sensitive to program planning factors and the degree of achieved booster processing friendliness. Reductions in cost estimates and schedule risks may be realized through the implementation of sweeping innovation (other than currently planned processing enhancements ie., electronic scheduling - LPS II).

Some technologies and relief might be incorporated into the design of the LRB and its planning. This could reduce processing time, processing errors, and GSE/LSE requirements. Further study and continued utilization of the KSC checklist is needed to help achieve these ground processing efficiencies. The goal is to develop a ground processing friendly booster.

Relief from select program planning factors which may offer substantial reductions in launch schedule risks are:

Reduce launch rate during transition

- Lessen shared resource impact

Greater emphasis on independent off-line facility and ground processing i.e., developing a new super pad.

- Assume mate/many booster processing activities
- Non- disruptive to STS/SRB operations
- May minimize other facility impacts
- Would delay initial LRB operations due to time for activation

Features which make the LRB more ground processing friendly (and should be incorporated into the final selected option) will:

- Reduce and simplify scheduled (generic) processing tasks
- Make ground processing GSE/LSE easy to use and reliable

- Minimize the need to introduce modifications into ground processing
- Provide high booster ground reliability
- Minimize testing and inspections

Finding 7: The KSC LRB program costs are approximately $1 billion dollars non-recurring and $1 billion dollars recurring, for a total of $2 billion dollars over a ten year life cycle (122 missions).

Major additional facilities (2 new Mobile Launcher Platforms and a Horizontal Processing Facility) and significant launch pad modifications are required for the STS/LRB program to support a launch rate of 14 per year. The non-recurring cost is $716M. A contingency adjustment of 25% has been added because of the uncertainty in program definition at this early stage. It should be noted that the STS/SRB program requires new facilities to reach a 14 per year launch rate.

The recurring LRB operations costs for 15 years and 122 missions is $700M. Once again this is adjusted for early program uncertainty. This is about the same as SRB recurring operations cost. This comparison has uncertainty because of processing differences. For example, LRB fuel is a KSC cost whereas SRB fuel is part of the production costs and covered by MSFC.

Seven different cost estimates were made during the study by Lockheed, General Dynamics, and Martin Marietta. There was wider variation in the non-recurring than in the recurring costs. The final two Lockheed estimates for KSC narrowed the variance. These estimates included "bottoms-up" analysis and results from the Ground Operations Cost Model (GOCM).

Very small differences (about 6%) were shown between LOX/LH2 and LOX/RP configurations. This is well within the data tolerance.

SECTION 2
STUDY APPROACH

Our study approach was to formulate a task oriented study to assess the LRB integration into the on-going KSC STS operation. A core team of dedicated specialists was organized. Each study task was assigned a task leader from the core team. The study team had direct access to KSC resident LSOC/SPC ground processing expertise.

The basic study requirements were:

- Current KSC STS operations and facilities are the baseline
- Achieve an operationally efficient LRB system
- Reduced Life Cycle Cost

The study methodology is illustrated in the study plan presented in Figure 2.2-1. The study tasks were designed to progress from the establishment of baseline requirements/scenarios through the impact analysis including MSFC project integration to the output of the study in the form of plans, products and cost model.

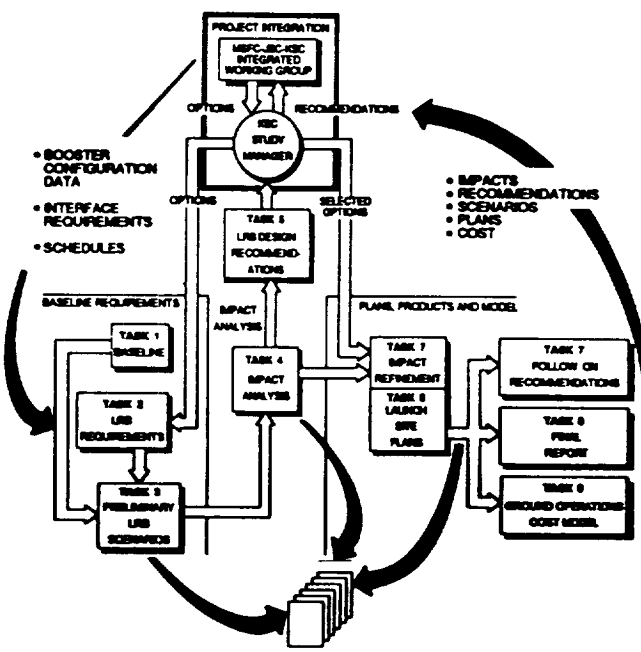


Figure 2.2-1. Study Methodology.

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SECTION 3
LRB Ground Processing Concept

An early review of ground processing requirements for LRB was accomplished with the use of the "KSC Requirements Checklist". The KSC design checklist was iterated with General Dynamics and Martin Marietta. A design requirements checklist was generated. The checklist also provided the LRBI Team with design processing requirements. It additionally served to focus the attention of the flight element designers on launch site capabilities, constraints and processing concerns. The LRB design teams were able to accommodate 75% of these requirements. The data obtained from the checklist was also used to formulate the STS/LRB Ground Processing concept, the basis of the Launch Site Plan.

3.1 APPROACH

The approach to LRB ground processing was constrained by the requirement of minimum impact to on-going launch site activities in a 14/year launch environment. It was also initially believed that the integration of STS/LRB into the KSC processing activity would be more easily accomplished with an independent off-line capability.

It was found that the LRB ground processing concept is insensitive to selected option. LRB ground processing scenarios, however, were found to be very sensitive to achieving transition and sustained launch rate requirements. Therefore the final selected processing scenarios was driven by schedule considerations.

3.2 GROUND PROCESSING CONCEPT

The ground processing concept is shown in Figure 3.2-1. A ten year activation period with an overlapping period of transition was employed. See Figure 1.2-2.

Processing activities were decentralized and removed from the VAB, thereby retrieving

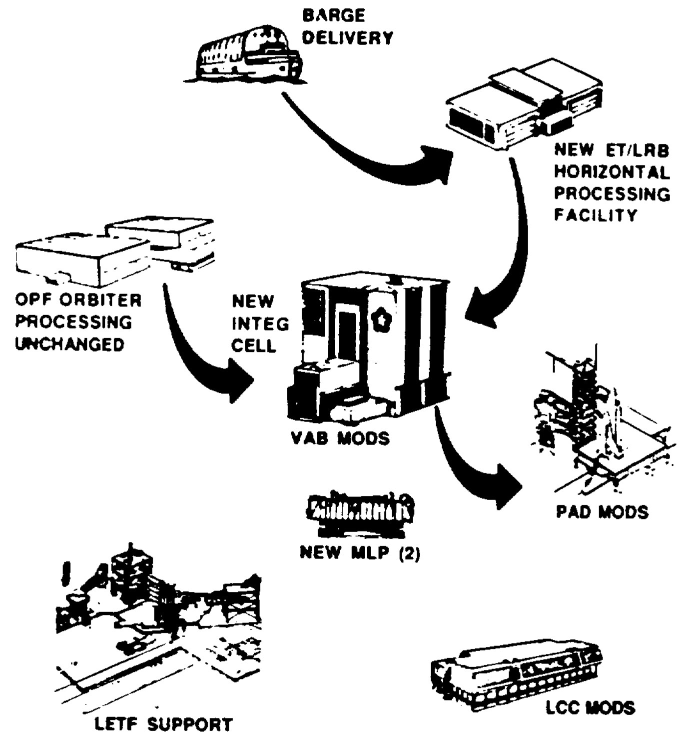


Figure 3.2-1. LRB Ground Processing Concept.

the VAB for integration activities. A new integration cell in the VAB is planned in order to meet the expected 14/year launch rate. All booster inspections and processing will be accomplished at a new ET/LRB Horizontal Processing Facility (HPF). The HPF will have a standalone checkout capability which relieves the LCC of performing these functions. All other processing activities remain unaffected.

The Ground Processing Concept requires two new MLPs, an HPF, and modifications to the Pad and LCC. It also requires increased support from the LETF.

SECTION 4
LAUNCH SITE PLAN

During the Liquid Rocket Booster Integration Study a preliminary Launch Site Plan was established. It covers the entire LRB life cycle at KSC including the activation period, (see Figure 4.0). The Launch Site Plan con-

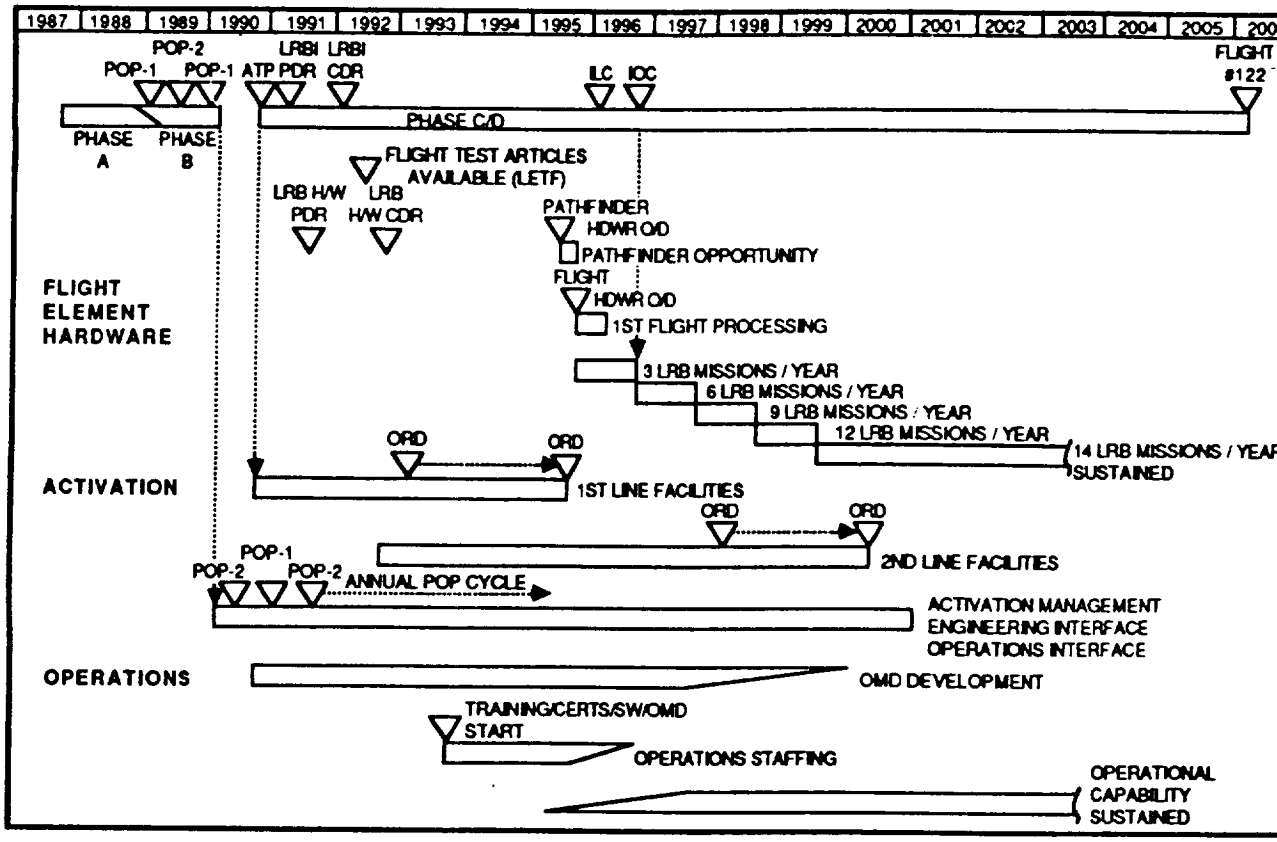


Figure 4.1. Launch Site Plan Schedule.

tains KSC LRB costs, manpower, and schedule projections. This section summarizes this plan. Greater detail is provided in the Launch Site Plan, Volume II, Section 2.

4.1 LRB INTEGRATION PHASES

The LRB program has been grouped into three phases to: (1) support the construction, modifications and preparations for the first LRB/Shuttle launches in 1996; (2) support the phased replacement of SRBs with LRBs; and (3) the full-up LRB operational phase to complete 122 LRB launches. These phases have been defined as 1. Facilities Activation; 2. Transition; and 3. Operational (see Figure 1.2-1).

The activities in the first two phases are planned to yield minimum impact to the ongoing KSC launch operations with SRBs until the SRB launches have been phased-out. A synopsis of the planned activities is shown in Figure 4-0.

The activation phase is planned for a ten year period from the beginning of FY 1991 until the end of FY 2000. Activities in this period include design, construction and activation for the first launch in early FY 1996; preparation of O&M documents; training/certification of personnel; demonstration tests/FRF with the pathfinder hardware; and completion of the facilities work in the latter half of the phase.

The transition phase is planned for the five year period from the beginning of FY 1996 until the end of FY 2000. This includes the overlap period of the last half of the activation phase and the first half of the operational phase. Activities in this period include completion of the remaining facility preparations to support sustained operational LRB launches; receipt of first operational hardware; graduated increase in LRB launch rate with a corresponding decrease in SRB launches; ILC at the first LRB launch; IOC at the fourth LRB launch; and phaseout of SRB launch capability.

The phased LRB launches consist of 3 in FY 1996, 6 in FY 1997, 9 in FY 1998, 12 in FY 1999, and 14 in FY 2000. At this time the SRB launches will be phased out and the LRBs will be the only Shuttle launches. This will result in 44 LRB launches during this phase.

A detailed study on this transitional phase is presented in Volume III, Study Product 9.

The Operational phase is planned for the ten-plus year period from the beginning of FY 1996 until the latter part of FY 2006. A sustained launch rate of 14 LRBs per year is planned during the latter part of this period. This decreases to eight launches during FY 2006 at program termination. This will complete the total of 122 launch missions projected for the LRB program.

4.2 NEW CONSTRUCTION

Selected new facilities must be designed and constructed to avoid impacts to the on-going STS/SRB launch program and provide compatibility with the new size/shape of the LRBs. These consist of two new MLPs and a new ET/LRB Processing Facility designated as the Horizontal Processing Facility (HPF). The HPF will also contain an LRB engine shop, a processing control center, and surge (storage) capability for two flights of ETs and LRBs.

4.3 MANPOWER REQUIREMENTS

As depicted in Figure 1.2-3, the LRB manpower requirement at KSC peaks in FY 1994-1995 at about 2000 people for booster processing and facility activation. This vividly portrays the resource impact associated with LRB activation and transition concurrent with SRB operations.

4.4 COST

The launch site plan provides a cost breakout by fiscal year over the life cycle at KSC. These costs are Rough Order of Magnitudes (ROM) and are provided for planning purposes only.

These costs are referred to in Volume II, Section 4, as the "bottoms-up" cost estimates. They compare favorably with those generated using the NASA Ground Operations Cost Model (GOCM) described in Volume II, Section 3.

SECTION 5
COST ANALYSIS

This study employed two major cost estimating exercises to develop a cost estimate. A "bottoms-up" approach using as source data the results generated by the study products, and The Ground Operation Cost Model (GOCM). The two approaches were compared, evaluated, and used in the generation of the final cost estimate.

5.1 "BOTTOMS-UP"

The Launch Site Plan, Volume II, Section 2 best summarizes the LRBI study data used in the "bottoms-up" cost estimate developed in the same volume. This estimate considers many cost elements, and represents the most complete cost estimates performed in the study.

5.2 GOCM

GOCM is a parametric cost model, and does not provide the same level of completeness as the "bottoms-up" approach. However, its cost estimating relationships were empirically derived and represent a certain level of realism, which may provide a greater accuracy than achieved in the "bottoms-up" approach.

5.3 COST PROJECTIONS

The "bottoms-up" and GOCM estimates are in fairly close agreement. They do, however, differ greatly from the General Dynamics and Martin Marietta estimates (see Figure 5.3-1). The study groups' costs are much more comprehensive in scope and represent

COST EST (FY87 B$)		NON-RECURRING	RECURRING	SUB - TOTAL	ADJUSTMENT (1)	TOTAL
1 KSC INITIAL CONCEPTUAL ESTIMATE		.476	.501	.977	40%	1.368
2 INITIAL GOCM		NA SINGLE FLEET LRB SRB	NA	NA	NA	NA
3A GENERAL DYNAMICS		.337	.488	.825	40%	1.155
3B MARTIN MARIETTA		.324	.501	.825	40%	1.155
4 KSC BOTTOMS-UP ESTIMATE	(3)	.705	.974	1.70	NA (2)	1.70
	(4)	.826	.974	1.80 (1)	NA (2)	1.80
5 FINAL GOCM ESTIMATE	LRB	.716	.700	1.42	25% (5)	1.78
	SRB	.373	.472	.845	25% (5)	1.06
6 FINAL LRB COST ESTIMATE	(6)	.700	1.00	1.70	NA (2)	1.70
	(7)	1.00	1.00	2.00	NA (2)	2.00

(1) NASA FACTOR @ 40% (FEE @ 10%, GOVT SUPPORT @ 5% AND CONTINGENCY @ 25%)

(2) INCLUDES 40% IN SOURCE DATA

(3) RP-1/LOX

(4) LH2/LOX

(5) INCLUDES FEE & GOVT SUPPORT, MUST APPLY CONTINGENCY

(6) MIN VALUE

(7) MAX VALUE

Figure 5.3-1. KSC LRB Life Cycle Cost Matrix.

a more refined projection of costs and impacts.

The final LRB LCC cost projection for KSC assumes the current launch pads can be employed with modifications as defined in the study (see Volume III, Section 3). The final KSC LRB LCC projection for ground processing and including activation is $1.7-2.0 Billion dollars. Volume II, Section 4 discusses cost element sensitivities and cost drivers.

SECTION 6
GROUND OPERATIONS COST MODEL (GOCM)

GOCM was found to be a very useful and flexible pre-Phase-A cost estimating tool which requires greater development to serve beyond the Phase-A study level. This study simplified GOCMs use by reprogramming it to be user friendly and expansion ready.

6.1 GOCM EVALUATION

GOCM needs to be expanded to perform mixed fleet (i.e. Shuttle and Shuttle derivatives) concurrent operation cost estimates. As a result of this study, GOCM can now perform mixed booster concurrent operation cost estimates.
GOCM also needs to be recalibrated to the post 51-L environment in order to assure confidence in its future estimates.

GOCM may not be relevant in the near term Post 51-L environment since it was derived in the Pre-51-L time period. GOCM currently adjusts its CERs to accommodate the Post 51-L environment. The most recent STS-26R launch processing times were larger than predicted by GOCM, inferring the model should not be applied to near term future scenarios. Another view, is that GOCMs more optimistic projections must be met if the launch ground rules (i.e. 14-15 missions per year) are to be achieved. Therefore, the estimates are believed to be relevant to the LRB study.

GOCM can not support post Phase-A studies which consider discrete design and support variations. Different cost estimating approaches need to be developed and incorporated into GOCM.

GOCM was found to be 80% accurate (20% low) when applied to the pre 51-L environment.

6.2 RECOMMENDATIONS

Two types of recommendations are presented. The first type builds on the existing GOCM model. The second rebuilds GOCM and is called GOCM II (see Volume III, Section 16).

6.2.1 Enhanced GOCM

The following enhancements are recommended:

- Calibrate GOCM (Post 51-L)
- Develop mixed fleet capability
- Expand modular approach

6.2.2 GOCM II

A new GOCM should be developed. It should utilize Phase A-D costing techniques, and develop launch rate capabilities, manning and costs for various mixed/single fleet configurations. The GOCM II effort will require the establishment of a dedicated full time custodial/development/user group.

SECTION 7
CONCLUSION

It is the overall conclusion (Figure 7-1) of the KSC-LRBI study that the 1990-2006 LRB integration scenario can be achieved.

The Liquid Rocket Booster Program can achieve 10 years of ground system and facility activation by 1999. In addition, 122 launches can be accommodated from 1996 to 2006. These milestones include a 35 launch transition phase with the SRB configured STS from 1996 to 2006.

- WE CAN ACHIEVE THE 1990 - 2006 LRB INTEGRATION SCENARIO
- THE PRINCIPAL RISK IS THAT THE LRBI ACTIVATION AND OPERATIONS IMPLEMENTATION MAY IMPACT THE 14 FLIGHTS/YEAR PROGRAM
- WE CAN ACCOMMODATE THE ENVIRONMENTAL AND SAFETY IMPLICATIONS WITH ESTABLISHED KSC POLICIES
- THE LIFE CYCLE COSTS AT KSC WILL BE LESS THAN 10% OF THE TOTAL LRB PROGRAM COSTS. THE KSC NON-RECURRING COST WILL BE LESS THAN 6%

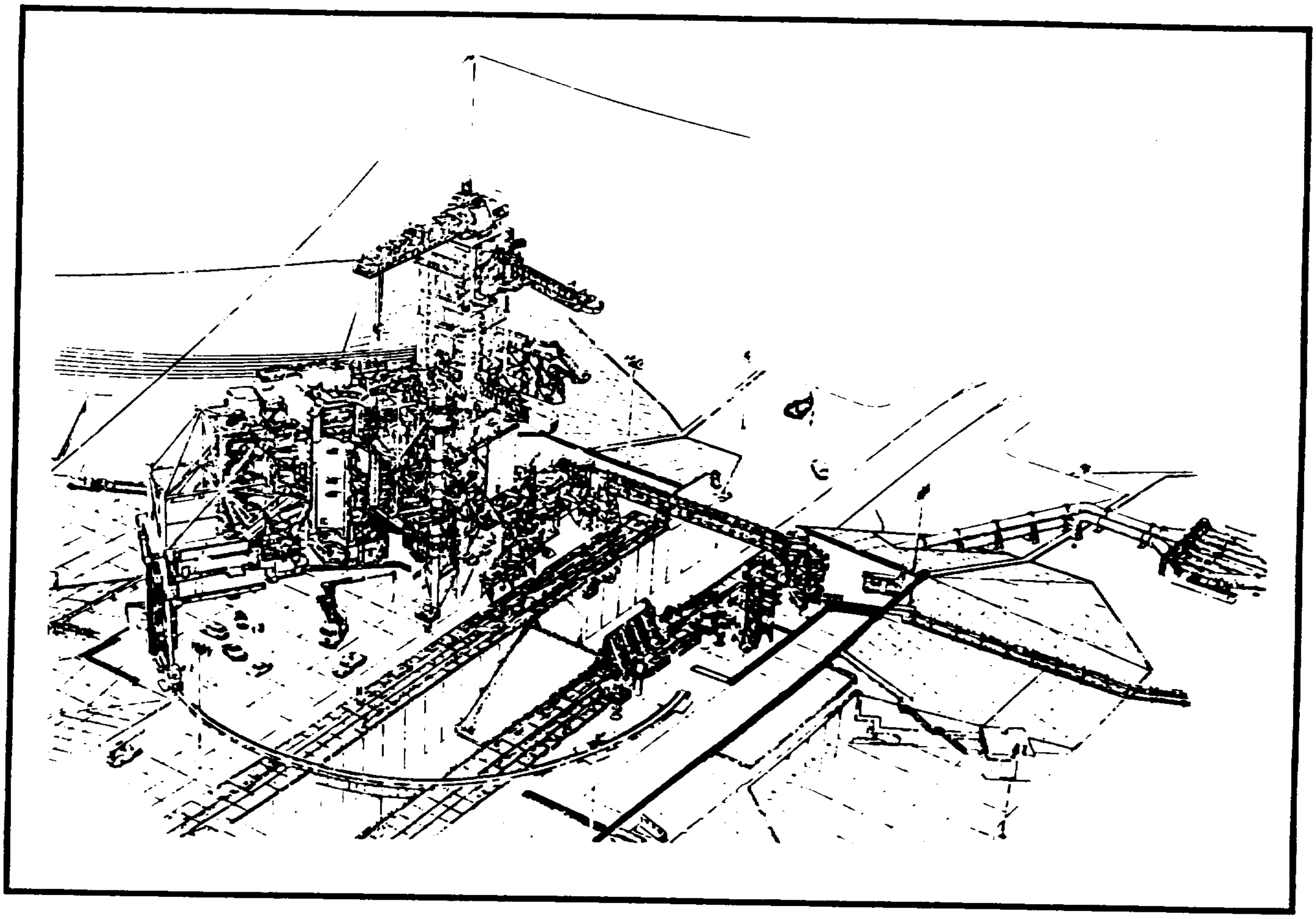
Figure 7-1. KSC LRBI Conclusions.

The major and unprecedented NASA/KSC challenge is the transition from STS/SRB operations to STS/LRB operations in a non-disruptive manner. A dedicated activation/implementation team will be essential to manage the risk.

The critical path for the activation to meet the first launch is the completion of a new LRB Mobile Launch Platform (MLP). In addition to the MLP construction and equipment installation effort, a complete systems checkout must be accomplished for the first launch. This will include fit checks at the VAB and PAD, cryo flows and support to the pathfinder static firing. Adding these efforts to the Pad time for the first 3 launches consumes 10-12 months of dedicated Pad access. Although some Pad access windows exist for SRB configured launches, there is a substantial element of risk.

The transition of the Shuttle program to Liquid Rocket Booster configuration generates a program Life Cycle Cost in excess of $15 Billion. The operations cost will be less than 9 or 10 percent of this Life Cycle Cost.

This study has: (a) Eliminated program/design options with major operations problems early in the development phase (for example, elimination of hypergols) and (b) identified areas that require a risk abatement plan early in the program development cycle. (The obvious example here is the activation team for assuring a successful transition).



Shuttle Launch Pad

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13. ABSTRACT *(Maximum 200 words)*
The impacts of introducing Liquid Rocket Boosters (LRB) into the STS/KSC Launch environment are identified and evaluated. Proposed ground systems configurations are presented along with a launch site requirements summary. Pre-launch processing scenarios are described and the required facility modifications and new facility requirements are analyzed. Flight vehicle design recommedations to enhance launch processing are discussed. Processing approaches to integrate LRB with existing STS launch operations are evaluated. The key features and significance of launch site transition to a new STS configuration in parallel with on-going launch activities are enumberated.

The LRB Integration Study Final Report is presented in Five volumes as follows:

VOL I Executive Summary
VOL II Study Summary
VOL III Study Products
VOL IV Reviews and Presentations
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